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MIDTERM RESULTS AFTER MINIMALLY INVASIVE CORONARY SURGERY (LAST OPERATION)

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Background: **Our experience with a left internal thoracic artery graft to the left anterior descending artery via a left anterior small thoracotomy is reviewed to evaluate midterm results.** ***Methods:*** **From November 1994 to April 1997, four hundred sixty patients were scheduled to undergo a left internal thoracic artery graft to the left anterior descending coronary artery via a left anterior small thoracotomy; 26 of these patients (5.7%) were converted and 434 of them had the operation. Two hundred fourteen patients (49.3%) had isolated disease of the left anterior descending artery, and 220 patients(50.7%) had multiple vessel disease. A sufficient length of the left internal thoracic artery was harvested to reach the left anterior descending artery.** ***Results:*** **Three hundred nine patients (71.2%) underwent extubation by hour 2. Mean intensive care unit stay was 4.2 ± 4.5 hours; mean postoperative hospital stay was 66 ± 29 hours; the 30-day mortality rate was 1.1%; the late mortality rate was 1.4%. Eighteen patients underwent reoperation early (≤30 days), and eight patients underwent reoperation late (>30 days) because of conduit/anastomotic malfunction. Four patients underwent reoperation with patent anastomosis for progression of disease (*****n***** = 3) or pericarditis (*****n***** = 1). Three patients had a percutaneous transluminal coronary angioplasty. Cumulating angiographic and stress Doppler flow assessment results, a patent anastomosis was obtained in 417 patients and a nonrestrictive anastomosis in 404 patients. Twenty-nine months after surgery, survival was 97.1% ± 0.7% (95% confidence interval**

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90.5% to 100%) and event-free survival 89.4% ± 1.2% (95% confidence interval 78.2% to 100%). In the last 190 patients, with our increased experience and better instruments, we obtained a patent anastomosis in 188 patients (98.9%) and a nonrestrictive anastomosis in 185 (97.4%). ***Conclusions:*** **Left anterior small thoracotomy gives acceptable midterm results. Incidence of patent and nonrestrictive anastomoses was satisfactory, especially in the most recent part of our experience, when the learning curve ended. (J Thorac Cardiovasc Surg 1998;115:763-71)**

Left anterior descending (LAD) artery grafting with the left internal thoracic artery (LITA) via a left anterior thoracotomy was introduced by Vassili Kolessov in the 1960s.[1] More recently, other authors, such as Benetti and Ballester,[2] Acuff and associates,[3] Robinson and associates,[4] and Subramanian and Stelzer,[5] reproposed the same operation with only a few modifications. The possibility of grafting the most important coronary artery, using the most important arterial conduit,[6] generated a great deal of interest, even if some concern still exists about some technical aspects and if midterm results are not yet well known.

Our experience began in November 1994. We report our results with LITA to LAD grafting via a left anterior small thoracotomy (LAST) on a beating heart.

Patients and methods

From November 21, 1994, to April 20, 1997, 460 patients were scheduled for LITA to LAD grafting via a LAST on a beating heart; in 26 of them (5.7%) the operation could not be accomplished, and a median sternotomy was performed. The preoperative data of the 434 patients who underwent the procedure are shown in Table I.

Surgical indications. Candidates for the LAST operation are patients with a LAD disease where (1) a (stent) percutaneous transluminal coronary angioplasty (PTCA) is not feasible because of technical aspects, (2) the surgical procedure is chosen by the cardiologist or the patient himself, or (3) a restenosis after a (stent) PTCA occurs.

Patients with multiple-vessel disease can undergo the LAST operation in selected cases. Assuming that the LAD lesion is suitable for surgery, the other coronary vessels must be (1) occluded and refilled by collateral circulation, (2) related to previously infarcted areas, (3) not graftable because of technical aspects (for example, distal stenoses with small coronary size, heavy calcifications), and (4) suitable for an integrated approach.[7] This group of patients is a very select group and needs only a single LAD graft. Therefore we are not proposing to perform a single LAD graft in multiple-vessel disease.

Where the cardiopulmonary bypass is itself the cause of high postoperative morbidity because of concomitant risk factors (Table I), patients can benefit from LITA to LAD grafting on a beating heart as a palliative operation.

Anatomic contraindications. The site for anastomosis is below the second diagonal branch; therefore our attention has to be addressed to this portion of the LAD. An intramyocardial, calcified, small-sized (< 1.5 mm) LAD should be avoided, when these anatomic aspects can be recognized before surgery at angiography. Sometimes the heart is rotated to the right; in this situation the position of the LAD becomes substernal and the anastomosis is impossible to do. Unfortunately, these patients could not be identified before the operation, even with increasing experience.

Anesthetic management. Anesthesia is induced with fentanyl and sodium thiopental and is maintained with fentanyl and droperidol. Muscular relaxation was obtained with pancuronium bromide. A Carlens tube was used in the beginning of our experience to avoid left lung ventilation if necessary, but its use is now discontinued. At the beginning of the procedure, a continuous infusion of diltiazem (10 mg/hr) is begun; small boluses (10 mg) are injected, when necessary, to obtain a heart rate of 45 to 50 beats/min. In the final part of the operation a mixture of nitrous oxide and oxygen is used, to allow a rapid awakening of the patient.

Surgical technique. The patient is positioned on the operating table in the supine position as usual. The chest is opened via a LAST in the fourth or fifth intercostal space, according to the angiographic anatomy; the pleural cavity is always opened. The ribs are retracted. No costal cartilage is resected; however, sometimes the condrosternal joint breaks by itself: it will be reconstructed during the wound closure. The pericardium is opened to assess the feasibility of the procedure. The LITA is then identified and dissected. In the first part of our experience,[8] we harvested a short segment of the LITA. More recently, with increasing experience and new instruments, if necessary, a much longer segment can be harvested. The conduit is harvested distally up to the bifurcation and proximally for the length necessary to reach the LAD. For this purpose, in the last 190 cases, we used a new retractor[9] (Cardio Thoracic System, Cupertino, Calif.) that pulls up the chest wall and exposes the LITA very clearly; the conduit can be easily dissected, skeletonized, or pedicled up to the first rib, if necessary. Heparin (1 mg/kg) is given, and the distal LITA is ligated and transected. Five milliliters of a solution with papaverine (1 mg/ml) is injected into the distal tip, which is then clipped.

Table I. *Preoperative data (434 patients)*

Age (yr)	61.1 ± 9.9 (mean, 32-88)
≥70 yr	85 (19.6%)
Sex (female)	54 (12.4%)
Unstable angina	126 (29.0%)
Previous MI	130 (29.9%)
Major risk factors	85 (19.6%)
Age >75 yr	27 (6.2%)
Redo	14 (3.2%)
Diffuse encephalopathy	13 (3.0%)
Malignancy	13 (3.0%)
Renal failure	10 (2.3%)
Diffuse vasculopathy	4 (0.9%)
Untouchable aorta	3 (0.7%)
Coagulation disorders	2 (0.5%)
HIV positive	1 (0.2%)
Hepatic cirrhosis	1 (0.2%)
Single-LAD disease	214 (49.3%)
Multiple-vessel disease	220 (50.7%)
LM disease	17 (4.0%)
EF (%)	61.5 ± 12.9 (15–90)
≤ 35	13 (3.0%)

MI, Myocardial infarction; *LAD,* left anterior descending; *LM,* left main; *EF,* ejection fraction.

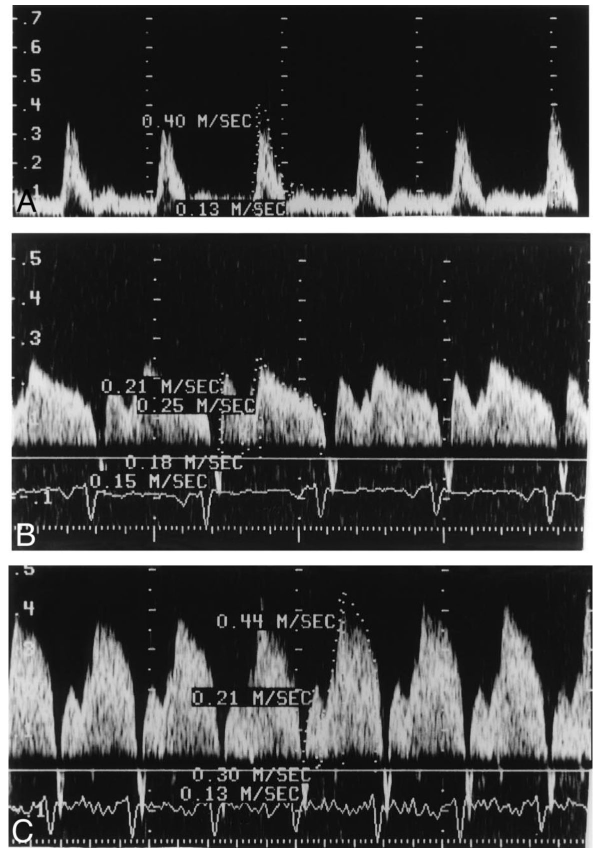

Fig. 1. A, The flow velocity pattern on the ungrafted LITA shows a dominant systolic component. **B,** When the LITA is anastomosed to the LAD, the diastolic flow velocities increase and often become higher than the systolic values (peak 25 vs 21 cm/sec, mean 18 vs 15 cm/sec). **C,** During the Azoulay maneuver, all the diastolic velocities increase further (peak from 25 to 44 cm/sec, mean from 18 to 30 cm/sec).

A second retractor, to be used for the distal anastomosis, is then positioned. The LAD is occluded proximally and distally with a 4-0 polypropylene (Prolene; Ethicon, Inc., Somerville, N.J.) suture with a 25 mm needle, passed deeply to surround the vessel. To avoid any direct compression of the suture on the coronary wall,[8] both needles are passed through a small piece of silicone tubing. Both 4-0 sutures are gently snared to ensure an operative field as bloodless as possible. A stabilizer with two feet (Cardio Thoracic System) connected to the retractor is positioned parallel to the LAD and pushed down gently. The up and down movement of the heart is stabilized; as a consequence, the LAD remains steady and its movements are nearly abolished. In no case is preconditioning of the distal LAD territory performed. The distal LITA is prepared in the usual manner; the LAD is dissected and incised. The anastomosis is performed with two 8-0 Prolene sutures with 6 mm needles.[8] Both of them are passed three times at the heel and at the apex; the LITA is then pulled down to reach the LAD. The two edges of the vessels now face each other, and the anastomosis is completed with two running sutures from both sides. The LITA and the LAD are then unclamped and the hemostasis is checked. Heparin is reversed with protamine (1/1); more recently, we have ceased to reverse heparin. A drain is positioned in the chest together with a small catheter to infuse an analgesic drug (bupuvicaine). The wound is closed as usual.

Postoperative course. All patients were admitted to the intensive care unit, where blood samples, a chest roentgenogram, and an electrocardiogram were obtained. The flow velocity pattern in the LITA was assessed by Doppler echocardiography. Because the LITA remains partially in its natural position, the flow pattern is easily detectable. The increase of the diastolic component of the flow velocity pattern is considered a demonstration of patency of the anastomosis, even if nothing can be said about its quality.

A few hours later, the patients were transferred to the ward. The drain and the intrapleural catheter were removed on the morning of postoperative day 1. A new Doppler echocardiography flow velocity assessment is then repeated, at rest and during the Azoulay maneuver, as proposed by one of the authors (S.G.).[16] If both of the patient's legs are lifted up, first passively, then leaving the patient alone to perform an isometric exercise, acute hypervolemia is induced, with an increase of the cardiac output and heart rate. If the Doppler echocardiography flow is recorded at rest and during the Azoulay maneuver, an increase of the diastolic flow can be observed (Fig. 1). Angiographic studies clearly show that this pattern is characteristic of a nonrestrictive anastomosis (unpublished data).

Table II. *Perioperative data*

LAD occlusion time (min)	25.3 ± 8.0
Anastomotic time (min)	18.3 ± 5.8
Operation time (hr)	2.1 ± 0.5
LAD grafting	
LITA (%)	398 (91.7)
IEA	
Elongation (%)	32 (7.4)
Bridge from LITA (%)	1 (0.2)
SVG elongation (%)	3 (0.7)
Diagonal grafting (IEA as Y graft) (%)	2 (0.5)
Associated surgery (%)	6 (1.4)

LAD, Left anterior descending; *LITA,* left internal thoracic artery; *IEA,* interior epigastric artery; *SVG,* saphenous vein graft.

Many patients had a postoperative angiogram, mainly for study purposes. However, every patient in whom an anastomotic malfunction was suspected had an angiogram. Thus patients were also, in part, selected for arteriography.

In the morning of postoperative day 2, most of the patients were discharged.

Follow-up. Follow-up for all patients was performed at our outpatient clinic at the end of postoperative months 1 and 6; eighty-six of them had only a single visit because they had not completed a 6-month postoperative period. All patients performed a stress test and, if possible, a myocardial scintiscan was obtained on the second visit. LAD flow velocity evaluation at rest and during the Azoulay maneuver was also repeated.

The follow-up was 100% complete; it ranged from 25 days to 29 months (mean 13.5 ± 7.8).

Statistical analysis. Results are expressed as mean value (standard deviation unless otherwise indicated). Statistical analysis comparing the two groups was performed with unpaired two-tailed *t* testing for the means or χ^2 test for categoric variables. Survival and event-free survival curves were obtained with the Kaplan-Meier method (BMDP 1L software, Los Angeles, Calif.). The statistical significance was calculated with the Mantel-Cox test and z-test. When necessary the confidence intervals (CIs) were added.

Results

In 26 patients (5.7%) the LAST operation was not accomplished because the LAD was not visible (16 cases), was calcified (4 cases), was substernal (3 cases), or was too small (2 cases) or the LITA was injured during the harvesting (1 case). All patients had an uneventful operation via a median sternotomy.

Surgical details. The fourth intercostal space was used in 181 patients (41.7%), the fifth in 234 patients (53.9%), and both in the remaining 19 patients (4.4%). In the first part of our experience, we preferred to use the fifth intercostal space, but more recently the choice is determined by the surgical anatomy of the LAD, detectable at angiography (that is, intramyocardial position, distal size). Both intercostal spaces were opened in a few cases because of the necessity to find a suitable anastomotic site.

Table III. *Postoperative data*

	N (percent of total)
Extubation	
OR	141 (32.5)
ICU (first 2 hr)	168 (38.7)
Bleeding (ml/12 hr)	149 ± 191
Redo for bleeding	6 (1.4)
Transfusions	10 (2.3)
Mean CK-MB peak (IU)	20 ± 15
Mean ICU stay (hr)	4.2 ± 4.5
Atrial fibrillation	35 (8.0)
Pericarditis	3 (0.7)
Postoperative in-hospital stay (hr)	66 ± 29
Discharged by postoperative day 2	295 (8.0)
Delayed chest-wound healing	12 (2.8)
Late pulmonary hernia	2 (0.5)

OR, Operating room; *ICU,* Intensive care unit.

Perioperative and postoperative data are shown in Tables II and III.

Early and late deaths. During the first 30 days after surgery, five patients (1.1%) died after a mean of 6.8 ± 7.5 days. Cause of death was cardiac, but not operation related, in four patients (sudden death from inferolateral myocardial infarction with widely patent graft at necropsy; low output syndrome, present before surgery and not reversed by the graft, widely patent at necropsy; cardiac tamponade in a patient who had a successful stent PTCA on the right coronary artery 3 days after the LAST procedure; cardiac failure early after a stent PTCA on the circumflex artery) and non-cardiac related (massive intestinal infarction) in one patient.

After 30 days from surgery, six patients (1.4%) died after a mean of 130 ± 120 days from the procedure. Cause of late death was cardiac in three patients, operation related in one patient (multiorgan failure in a patient who had simultaneous carotid endoarterectomy, femorofemoral bypass, and LAST operation; bleeding from a LITA collateral caused hypotension; and renal failure, the primary cause of the problems), and not operation related in two patients (both patients had myocardial infarction in a previously not diseased circumflex artery, and both were receiving long-term dialysis treatment; one of them had necropsy that showed a widely patent anastomosis). In the last three patients, the cause of death was not cardiac

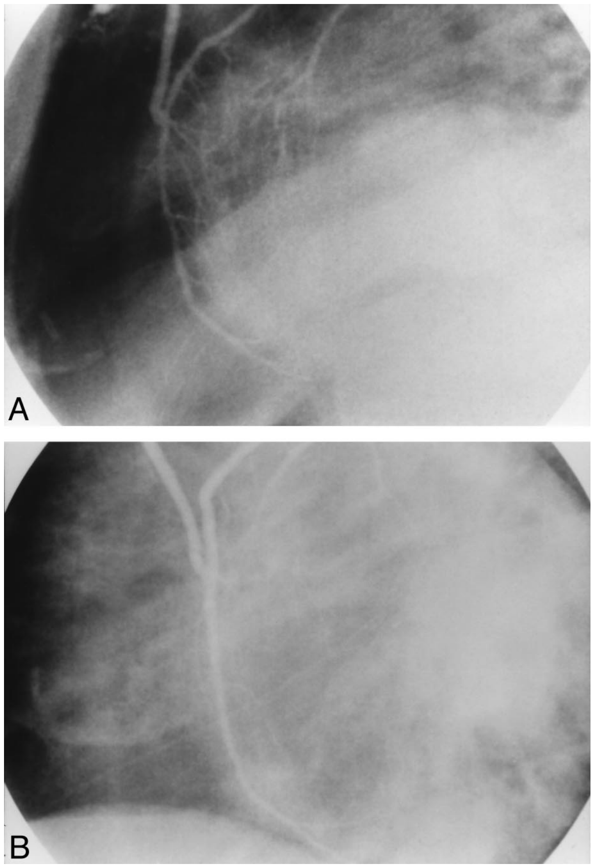

Fig. 2. Angiograms performed 24 hours (**A**) and 23 months (**B**) after the procedure. The anastomosis is unchanged, and no intimal hyperplasia is present at the occlusion sites in the LAD.

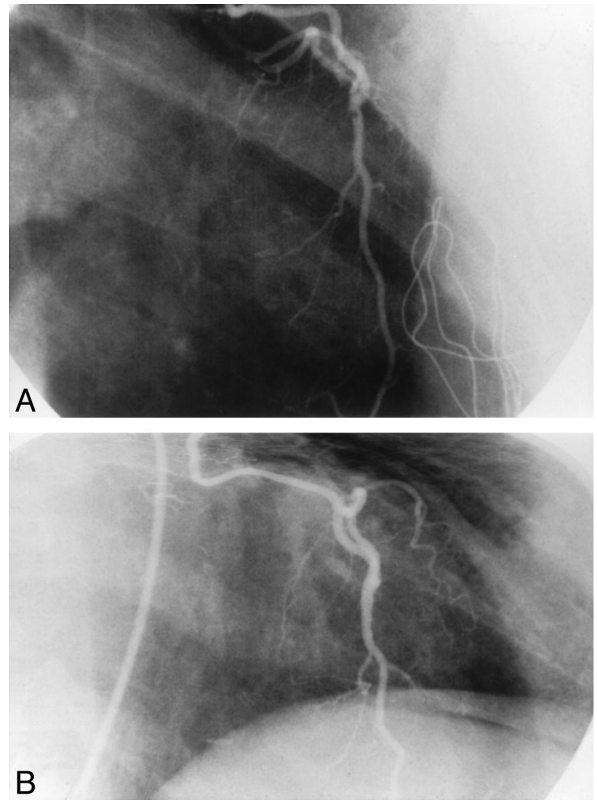

Fig. 3. Angiograms performed 48 hours (**A**) and 38 days (**B**) after the procedure. The severe stenosis, shown in **A** and not visible in **B**, is likely due to a clot.

(malignancy; cerebral hemorrhage; hepatic cirrhosis).

In total, of 11 patients who died, 10 had a patent anastomosis, demonstrated by angiography (3 patients), Doppler flow velocity assessment during the Azoulay maneuver (3 patients) or at rest only (1 patient), or necropsy (3 patients). The last patient died late of hepatic cirrhosis after a successful reoperation with cardiopulmonay bypass for graft occlusion.

Further revascularization on the target coronary vessel. Twenty-six patients (6.0%) had a redo for anastomotic stenosis (10 patients) or graft occlusion (16 patients) 18 patients (4.2%), during the first 30 days from surgery (mean 5.2 ± 5.3); and 8 patients (1.8%), after the first month (mean 138 ± 111 days). All patients underwent an uneventful reoperation, via a median sternotomy in 25 patients and a re-LAST in 1 patient, 24 patients with cardiopulmonary bypass and 2 patients remaining off pump. As previously reported, one patient died late of hepatic cirrhosis.

The incidence of reoperation is decreasing with time because experience is increasing and because new instruments are now available. In the last 190 patients there were four reoperations, 2.1% (for anastomotic stenosis in 2 patients and conduit occlusion in 2 patient), with a p value < 0.001 versus the remaining patients.

Three more patients (0.7%) needed catheter revascularization. The first one had a successful protected infrastent PTCA of the LAD because of an early anastomotic stenosis. At the routine angiographic follow-up (4 months later), the anastomotic stenosis disappeared. A second patient, with an asymptomatic anastomotic stenosis detected after an early routine angiogram, had a successful PTCA of the anastomosis 126 days after surgery. An anastomotic stenosis later developed in a third patient after an early perfect result on angiographic follow-up; it was successfully dilated 153 days after surgery.

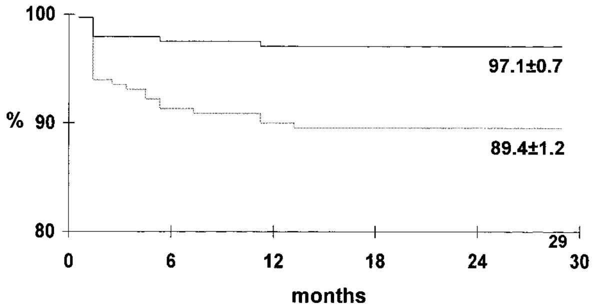

Fig. 4. Survival *(solid line)* and event free survival *(dotted line)* 29 months after the procedure.

Reoperations with patent conduit. Four patients (0.9%) underwent reoperation with patent distal anastomosis (1 to 119 days, mean 55.0 ± 53.6 days), two of them early (1 and 3 days, for inferior evolving myocardial infarction caused by occlusion of a previously moderately diseased right coronary artery and for unstable angina caused by subocclusion of a previously mildly stenosed marginal branch) and two of them late (97 and 119 days, the first one for recurrent severe pericarditis and the second one for a new LAD lesion, proximal to a distal patent anastomosis, not related to the LAD occlusion during the first procedure: the same LITA was used for an intermediate anastomosis leaving the distal portion intact).

Integrated approach. Eleven patients (2.5%) had a scheduled postoperative (stent) PTCA on the circumflex or right coronary arteries (three procedures in other institutions). All procedures were successful; unfortunately, for different reasons, two patients died, as previously described.

Quality control of the anastomosis. All the patients had a Doppler echocardiography flow velocity assessment at rest or during the Azoulay maneuver. However, as in conventional surgery, the Doppler flow assessment and the stress test can demonstrate that the operation had a good result, but not the anatomic details. In 271 patients (62.4%) a postoperative angiography was performed during the first year after surgery. The anastomosis was patent in 254 cases (patency rate 93.7%) and patent without any malfunction in 241 cases (perfect patency rate 88.9%). In total, after results were accumulating from angiography and Doppler echocardiography, a patent anastomosis was obtained in 417 patients (96.1%) and a nonrestrictive anastomosis in 404 patients (93.1%).

Table IV. *Preoperative and postoperative data according to the extent of the coronary disease*

	Single-LAD disease (n = 214)	*Multiple-vessel disease (n = 220)*	*p Value*
Age (yr)	59.7 ± 9.6	62.4 ± 9.9	0.004
>75 yr	10	17	>0.2
EF (%)	64.2 ± 12.4	59.1 ± 12.9	<0.001
<35	4	9	0.144
Redo	3	11	0.075
Major risk factors	31	54	0.040
CK-MB peak (UI/L)	19.7 ± 16.4	20.9 ± 13.6	>0.2
ICU stay (hr)	4.1 ± 4.5	4.3 ± 4.8	>0.2
Postoperative hospital stay (hr)	65 ± 25	63 ± 30	>0.2
Deaths	1	10	<0.001
≤30 Days	—	5	0.081
>30 Days	1	5	>0.2
Anastomotic/conduit failure	10	19	0.175
surgical revision	9	17	>0.2
(stent)PTCA	1	2	>0.2
Alive, asymptomatic, with/without medical treatment	213	210	>0.2
Alive, asymptomatic, without redo/PTCA on LAD	203	192	>0.2
Survival (29 mo)	99.5 ± 0.5	95.2 ± 1.1	<0.001
Event-free survival (29 mo)	92.5 ± 1.5	86.8 ± 1.8	<0.001

LAD, Left anterior descending artery; *EF,* ejection fraction; *CK-MB,* creatine kinase MB; *ICU,* intensive care unit; *PTCA,* percutaneous transluminal coronary angioplasty.

Two groups of patients had postoperative angiography: the first included patients who accepted postoperative angiography only for scientific purposes, provided that this could be obtained in reasonable time; the second group included patients where a suspicion of anastomotic or graft malfunction was present after a Doppler flow velocity evaluation. For this reason the real angiographic patency rate is potentially higher than the values showed by us.

However, if we consider the last 190 patients, angiographic results are improving. In this series, 134 angiographies were performed: 132 were patent (patency rate 98.5%, CI 90.6% to 100%) and 129 showed no abnormality (perfect patency rate 96.3%, CI 93.8% to 98.7%). The total patency rate (angiography plus Doppler echocardiography) was 98.9% (CI 92.1% to 100%) (188 of 190), and 185 patients (97.4%) had a nonrestrictive anastomosis (CI 94.3% to 100%) (185 of 190).

A favorable unexpected event occurred: six patients, who had anastomotic or graft malfunction at follow-up angiography, showed reversal of the abnormality after an interval between the two angiograms of 94 ± 56 days (Fig. 2). This was probably due to small clots, which can disappear after a few weeks, or to adventitial hematomas, which also can reverse. It appears that no decision has to be made early after surgery. If any angiographic abnormality exists, a repeat angiogram is performed 2 to 3 months later. Because of this experience, we decided not to reverse heparin at the end of the procedure, hoping to limit clot formation; however, at this time we have no data to support this hypothesis, even though the hypothesis seems reasonable.

Twenty-seven patients underwent a repeat angiogram more than 1 year after surgery (mean 16.5 ± 4.2 months), to evaluate the stability of the anastomosis with time and to check the development of LAD irregularities or stenosis in the proximal and distal occlusion sites. No patient showed any changes in shape of the anastomosis or of the LAD (Fig. 3).

Clinical results. At a mean follow-up of 13.5 ± 7.8 months, 423 patients (97.5%) are alive and asymptomatic with or without medical treatment with negative stress tests in every case; 395 patients (91.0%) are alive, asymptomatic, and without a repeated surgical or cardiologic intervention on the LAD. Actuarial survival and event-free survival are shown in the Fig. 4. For the purpose of the curve, events were defined as deaths (any cause), acute myocardial infarction in the LAD territory, or necessity of further revascularization (surgical or in the catheterization laboratory) because of anastomotic or graft abnormalities.

No patient had a perioperative or late myocardial infarction in the target area. Thus LAD occlusion did not appear to produce any harmful effect, and the anastomotic technique was effective.

Comparison between patients with single-LAD disease and with multiple-vessel disease. In Table IV these two groups are compared according to preoperative and postoperative data; clinical results are also shown. Patients with multiple-vessel disease were older and had lower ejection fraction, previous coronary surgery, and higher incidence of major risk factors. Even if clinical results were worse than in those with the single-LAD disease, the two groups comprise different patient populations and any comparison has many limitations.

Discussion

Kolessov[1] pioneered LAD revascularization with the LITA on a beating heart via a left anterior thoracotomy, describing the same technique used today. Recently, Benetti and Ballester[2] modified the same operation, using a thoracoscope for LITA harvesting. Unlike them, others[4, 5] harvested the LITA under direct vision. The procedure gained popularity; however, even though many problems are solved, many concerns still exist on different surgical aspects. Partial or total LITA harvesting is one of them. Because, from the technical point of view, we do not need the total length of the LITA to reach the LAD, the possibility of flow competition with the LAD territory caused by the persistence of undivided LITA branches, has to be explored. The LITA, like all muscular arteries, has a mainly systolic flow, with a small percentage of diastolic flow (ratio diastolic/systolic flow < 0.3). When this artery is grafted to the LAD, the flow pattern changes abruptly because the diastolic component, LAD-related, becomes predominant. Thus because flow in a muscular artery is mainly systolic and in a coronary flow is mainly diastolic, competition of flow cannot exist, because they occur in two different hemodynamic phases, as demonstrated by Luise and associates[11] in the catheterization laboratory and by Kern and associates.[12]

Revascularization of the LAD can be accomplished with different techniques, and the place of the LAST operation has still to be determined. Stenting is gaining more popularity because results are improving compared with balloon angioplasty.[17] Surgical revascularization, using median sternotomy, aortic crossclamping, and cardioplegia, provides optimal early and late results. In this scenario, the role of minimally invasive coronary surgery is still to be defined. Lacking results from the randomized study we designed and started in January 1997, data from our experience with single-LAD disease seem to compare favorably with those in the literature, when midterm results of coronary artery stenting are reported.[18] However, these questions will be answered in the near future.

The LAST operation is a procedure that, in single-LAD disease, can provide acceptable results. Even if 29 months are insufficient to define the future of this surgical procedure, our results suggest that the LAST operation will have a well-defined role in the treatment of single-LAD disease. A learning curve has to be considered. However, with the experience developed by different teams and with new instruments, the procedure's duration can be shortened and, perhaps, eliminated. Randomized studies will give us the information we need to select the best treatment for each patient.

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Discussion

Dr. Steven R. Gundry *(Loma Linda, Calif.).* Their LAD occlusion time during the operation was 25 minutes. I suspect that if a cardiologist were to stand here and tell us that their angioplasty balloon occlusion time was 25 minutes for the LAD, all of us would be picketing the American College of Cardiology to shut down this dangerous procedure. However, have the authors assessed regional contractility in the distal LAD distribution late, that is, 1 year after the operation, to determine the effect of this prolonged occlusion time? Also, 25 minutes of occlusion time without consequence, as the authors report, suggests to me that perhaps the operation was not necessary at all in this distribution.

Now, the authors state that in 5.7% of cases the operation was aborted and had to be done with cardiopulmonary bypass. The authors also state that 7% of the patients required either an early or late operation or required a late PTCA to that vessel. This is added to the authors' contention in the manuscript that 2.6% of the patients were scheduled for a PTCA after the operation to other branches, and an additional 1% of the patients required other operations to other arterial branches later in their course, bringing their less than successful treatment to 11%, plus the 5.7% that could not be treated with this technique. That is a 17% failure rate within the reporting time.

The authors stated that a perfect patency rate at less than 1 year was achieved in 88.6% of the patients. Could the authors please contrast this to their experience in patency rate of single LADs done on the pump during a concurrent time period, not a previous time period as reported in their manuscript.

At 1 year the authors report that 90% of their patients are alive and asymptomatic with or without medical treatment. For us to assess the efficacy of this operation, the authors need to tell us how many patients 1 or 2 years after surgery were requiring medical therapy as a portion of their asymptomatic status, because the principle of coronary revascularization is to eliminate or at least extremely lessen medical therapy. Lastly, the authors need to tell us, do they believe that this operation, which they call the LAST procedure, is in fact the last operation?

Dr. Valavanur A. Subramanian *(New York, N.Y.).* I rise to congratulate Professor Calafiore for presenting an excellent and a very important paper in the area of minimally invasive coronary artery bypass surgery. I must acknowledge here that the regional cardiac wall mechanical immobilization to create a still coronary artery target site throughout the period of coronary artery anastomosis in this operation is an important concept, which was advanced by Professor Bos from the University of Utrecht. As you can see from the results, the effect of the regional cardiac wall immobilization has been a positive one. In our own institution, of 118 LITA to LAD anastomoses during the last year, 108 patients underwent complete angiography routinely 36 hours after surgery and Doppler echocardiography flow assessment of the function of the anastomosis. Our patency rate is equal to what Dr. Calafiore has reported, 97.2%, and the event-free survival rate is similar. I do think that the regional cardiac wall immobilization is an important and probably an absolutely essential step in this operation. I think it is analogous to the bailout stent, which eliminated the OR rate from the balloon angioplasty with a similarly striking effect.

Dr. Calafiore. Dr. Gundry, 25 minutes of occlusion time in the distal LAD does not give any problem to the myocardium. We know this from the experience with the beating heart via median sternotomy. When the cardiologist tries to open the proximal LAD, the balloon is open in the proximal LAD. This is a very dangerous portion of the LAD. We always perform our anastomosis below the second diagonal branch, and we know that this is always well supported with any patient. In using the transesophageal echocardiography we sometimes see reduction of the contractility, a modest impairment generally; but this is quickly reversed by the opening of the thoracic artery or by the reopening of the distal LAD. We do not precondition the myocardium. For this reason the time is a little bit longer because we occlude the LAD immediately before starting the anastomosis.

About the percentages, of course the operation is not perfect and we learned a lot of things during our experience. For instance, the percentage of patients converted reflects only the number of patients that are sent to us for the MIDCAB, the patients in bad condition. The 7% for a redo operation, or about 6% for a redo operation, as a result of the problems in the harvesting of the thoracic artery on the anastomosis reflects the learning curve. But, as you can see, the 4 to 5 months event-free survival is the worst period of this operation, and this is just the experience that we had during this time. Of course the results more recently are by far better, and we are just studying to see whether this operation has a future. But I think that all of these figures will be reduced with time, as we did in the last part of our experience.

The patency rate of the LITA to the LAD with a median sternotomy, however, is not 100%, as we would think. Concerning the patency rate of the LITA to the LAD in studies that followed many patients for a maximum of 2 to 3 months, we know that we lose at least 5% of the thoracic artery on the LAD in the immediate postoperative period. So for this operation, I think the results are as good as the other. But you must consider that we did many patients with multiple vessel disease because of a malignancy or high-risk factor. These patients will have medical treatment because they have other vessel disease.

The operation was surely a palliative operation. For this reason I wrote with or without medical treatment because this is the group of patients for whom the medical treatment is aggressive. The results in the single-vessel disease are by far better than the results in the multiple-vessel disease because of these problems. The patients are older and have high-risk factors. In single-vessel disease, the patients are younger and without risk factors.

About the LAST operation, yes, perhaps it is the last, but for me it is just an acronym. Only the future will say whether this is the last or just one of the other operations.